



ADVANCES IN NGL RECOVERY TECHNOLOGY

Achieving Ultra-High Ethane Recovery and Deep Ethane Rejection Capability

Presenter: Galip H. Guvelioglu Ph.D.

Co-Author: Fred Yamin

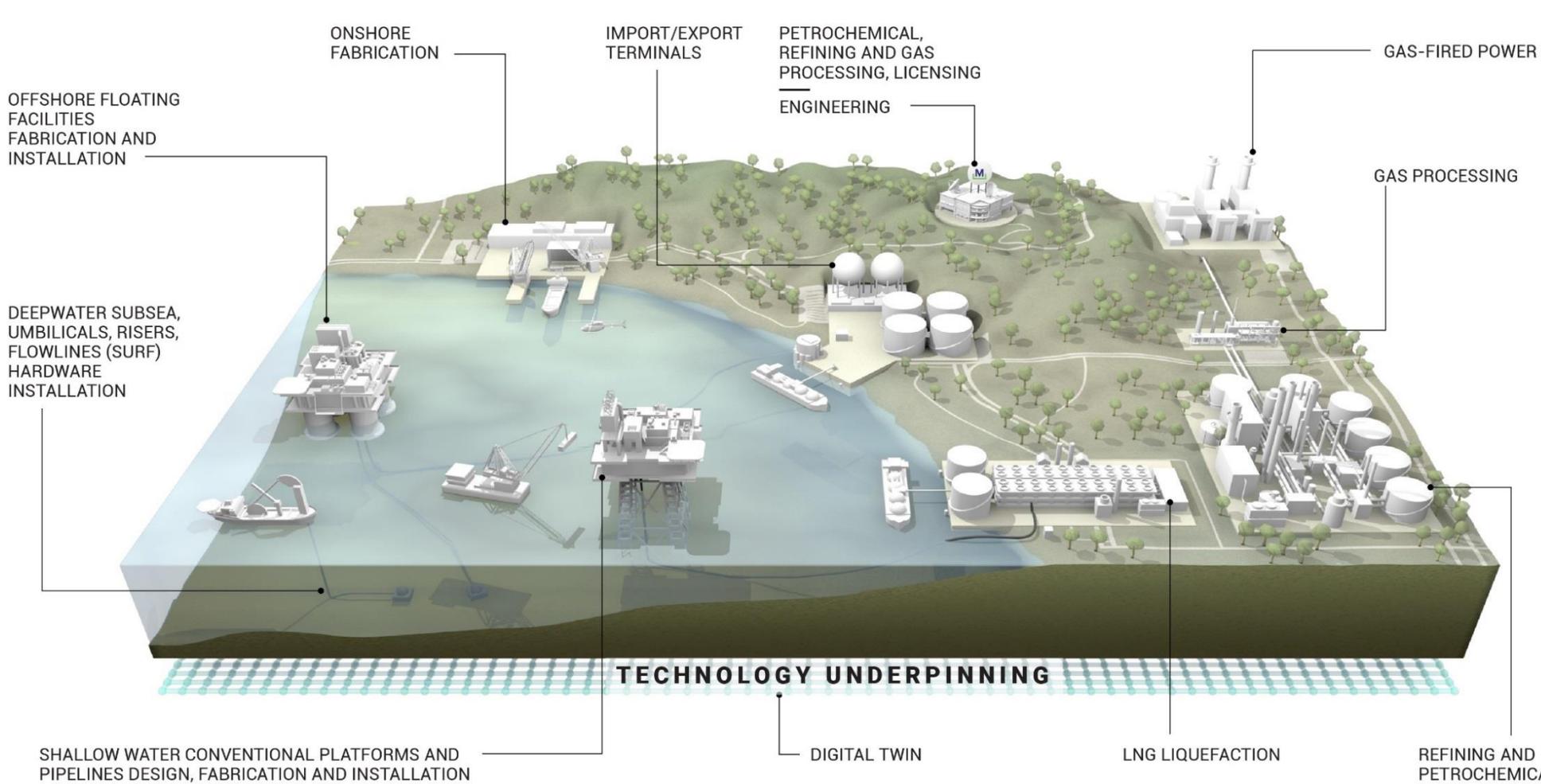
MCDERMOTT
TECHNOLOGY

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End-to-End Infrastructure and Technology Solution

UPSTREAM | DOWNSTREAM

SUBSEA > OFFSHORE > LNG > REFINING > PETROCHEMICALS > POWER



Lummus Gas Processing

- 300+ gas processing plants
- 200+ Turbo-Expander plants
- 26+ BSCFD gas processed

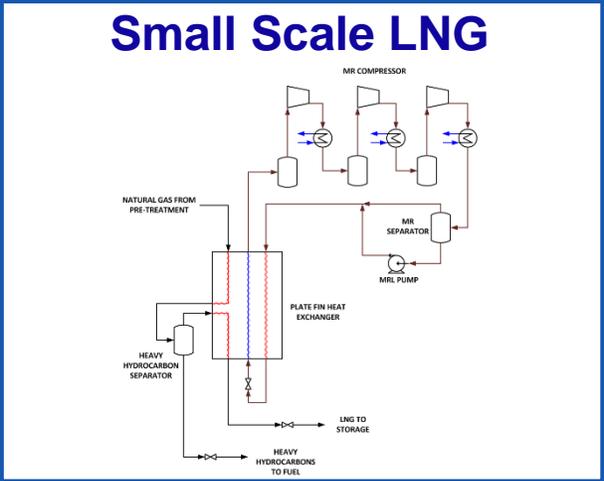
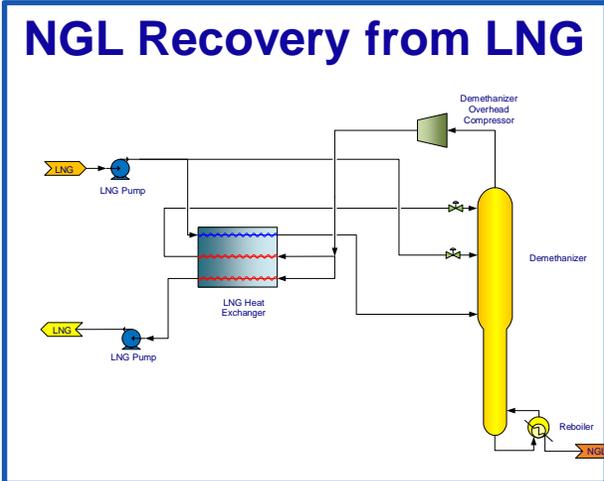
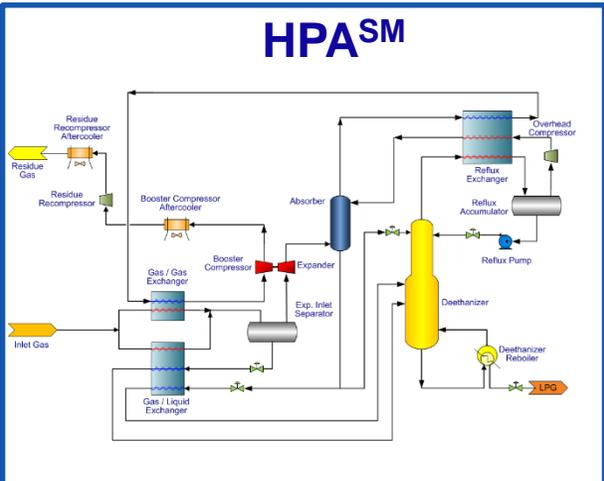
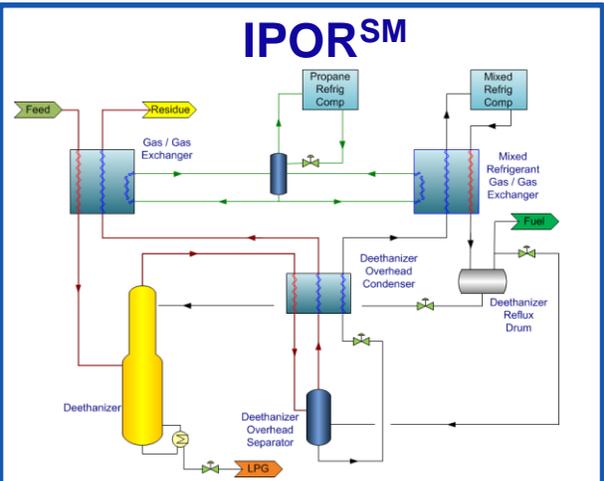
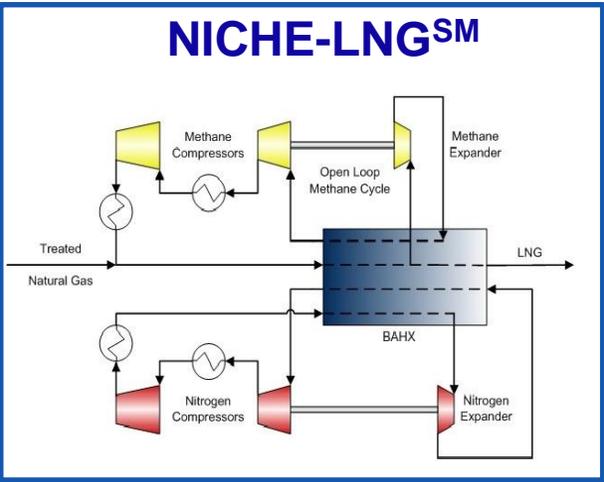
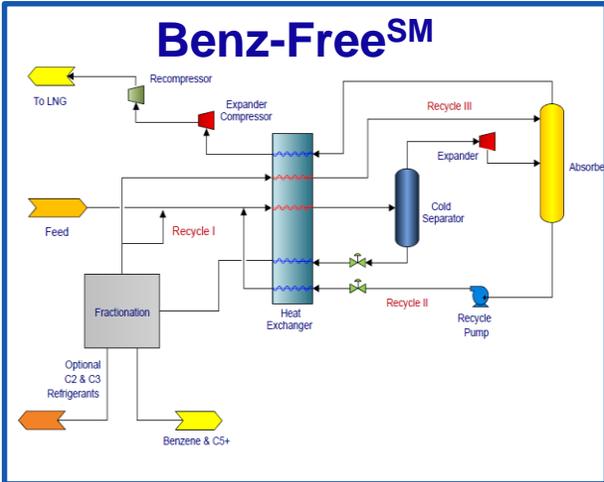
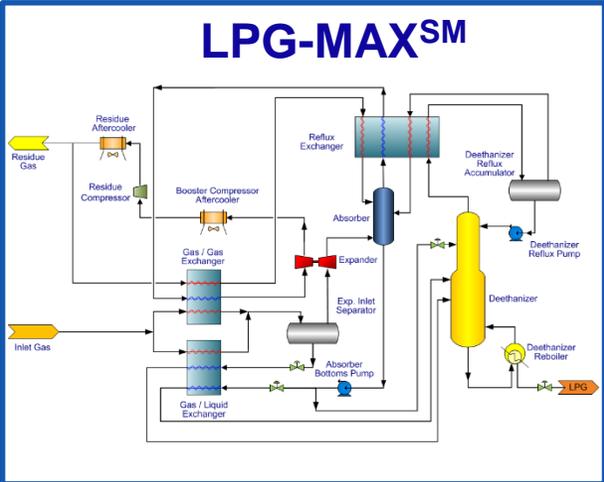
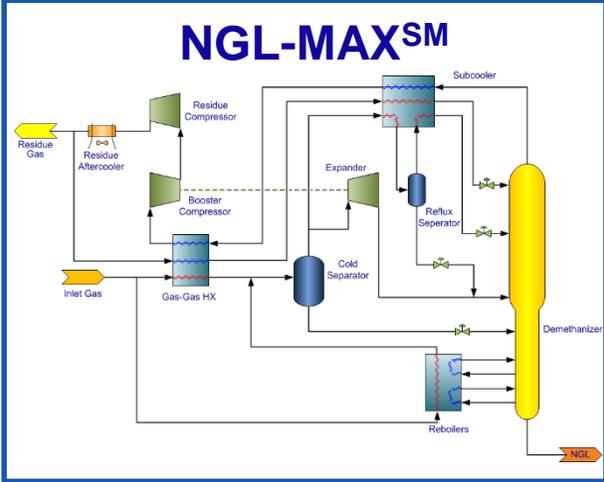
Experience includes:

- NGL/LPG Technology
- LNG Technology
- Nitrogen Rejection & Helium Recovery
- Amine treating units – Gas & Liquid
- Liquid Treaters
- Fractionation units
- Natural Gas Liquefaction (LNG Plants)

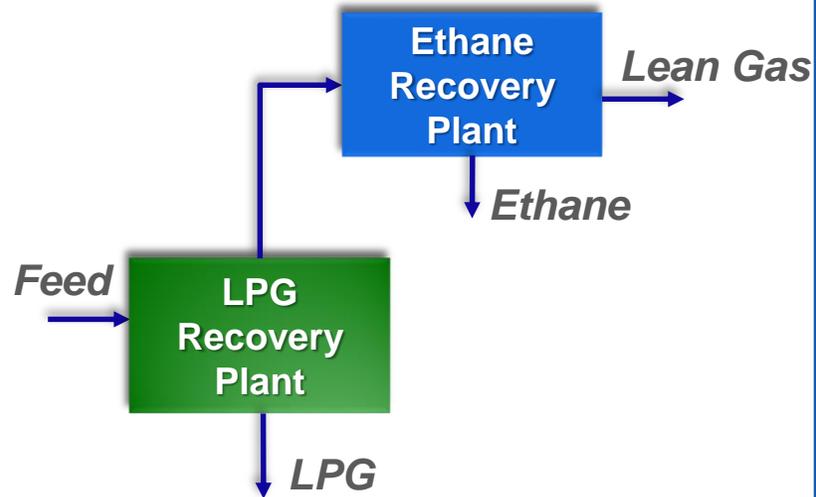


Hydrocarbon Recovery Technologies

LNG Technologies

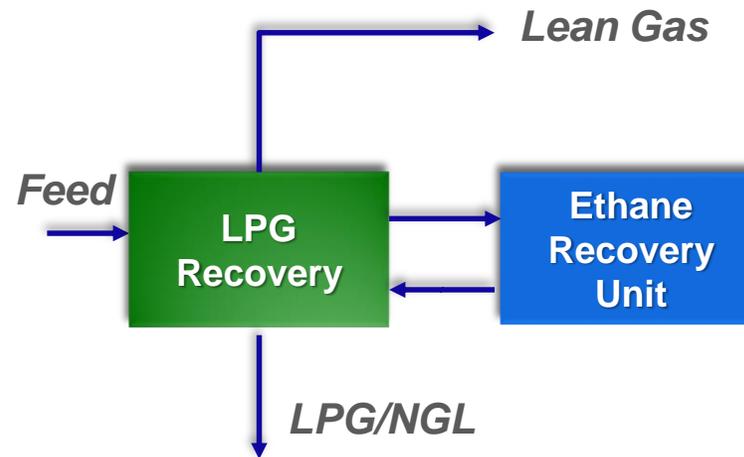


Future Ethane Demand
New Ethane Recovery Plant



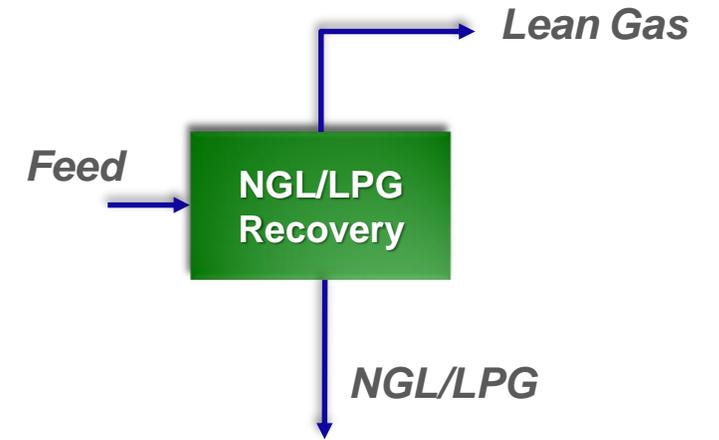
Lowest initial CAPEX and OPEX
Highest overall CAPEX and OPEX

Future Ethane Demand
Pre-invest in Ethane Recovery



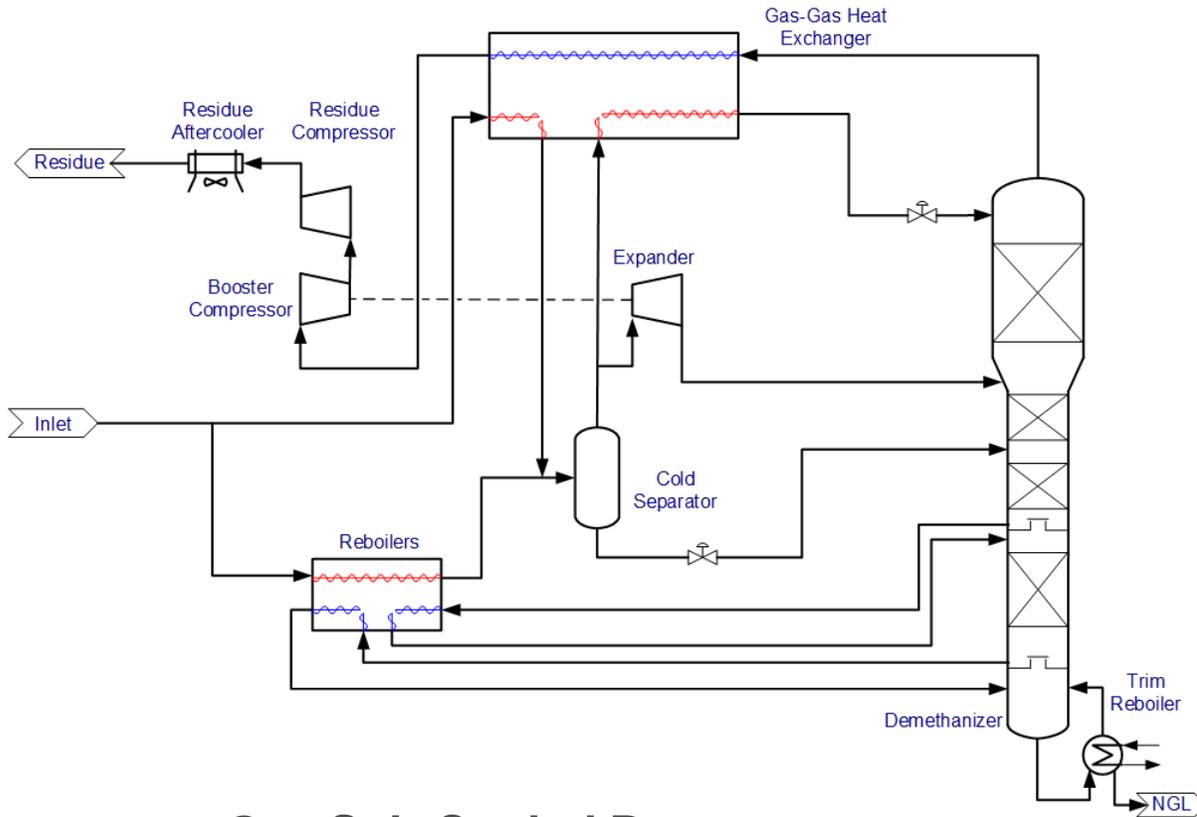
Higher initial CAPEX
Higher overall CAPEX
Lower OPEX

Ethane Price Volatility &
Future Ethane Demand
Dual Mode Process



Lowest initial/overall CAPEX
Higher OPEX in Rejection

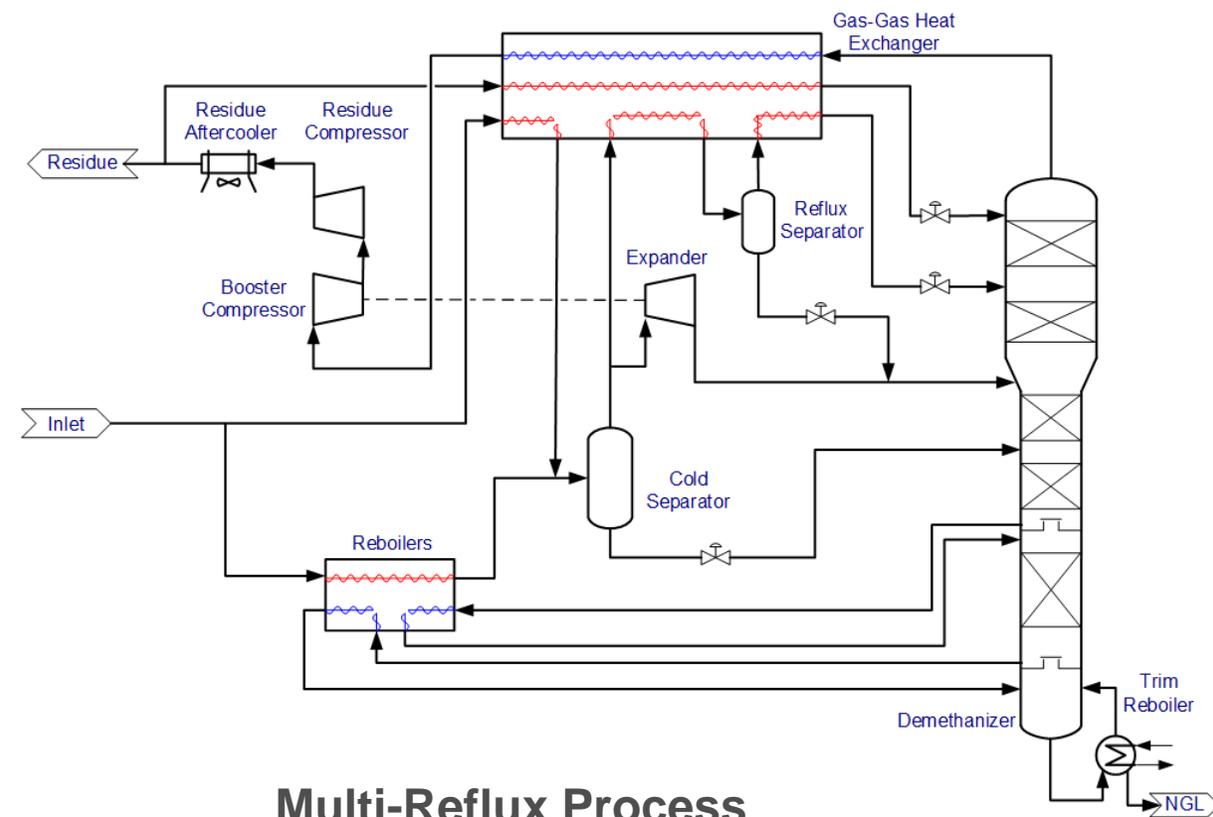
GSP – Open Art



Gas Sub-Cooled Process

- Most common Ethane Recovery Process
- Ethane Recovery/Rejection Capable

Lummus's NGL-MAXSM



Multi-Reflux Process

- Residue Recycle Reflux
- Semi-Lean Reflux
- Ethane Recovery/Rejection Capable

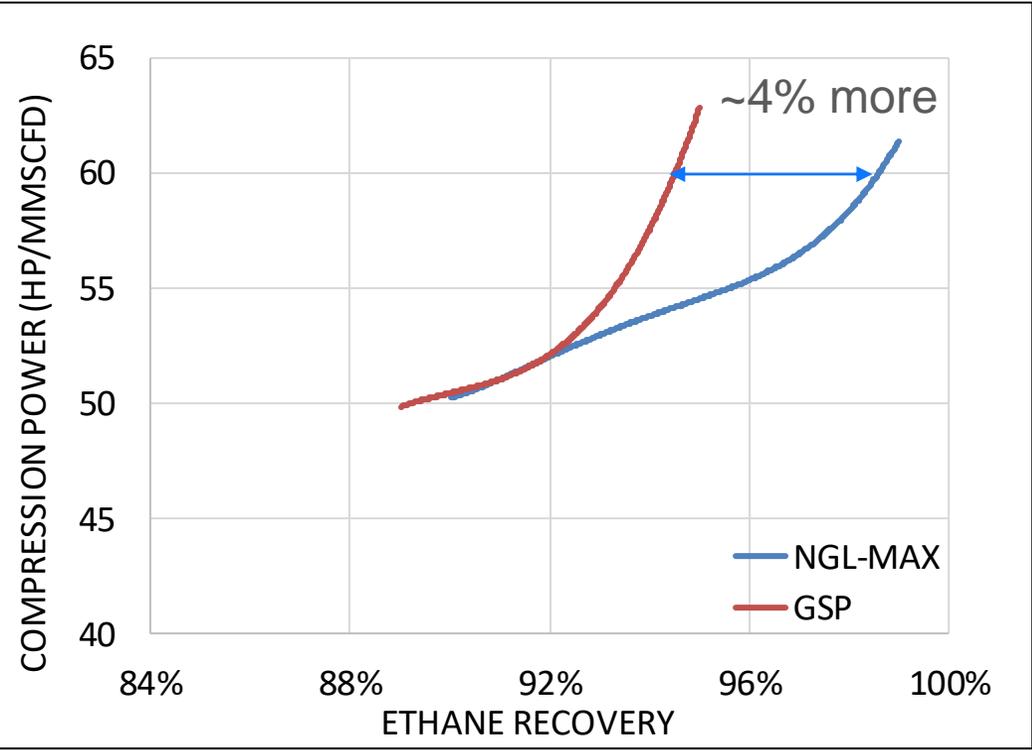
Parameter	Dehydrated Feed Gas
Pressure, barg	65
Temperature, °C	50
Flow, MMSCF/D	600
Component	Mol %
N ₂	0.3
CO ₂	0.5
Methane	88.1
Ethane	5.5
Propane	3.0
i-Butane	0.6
n-Butane	1.1
i-Pentane	0.4
n-Pentane	0.3
Hexane+	0.2

Product Specifications

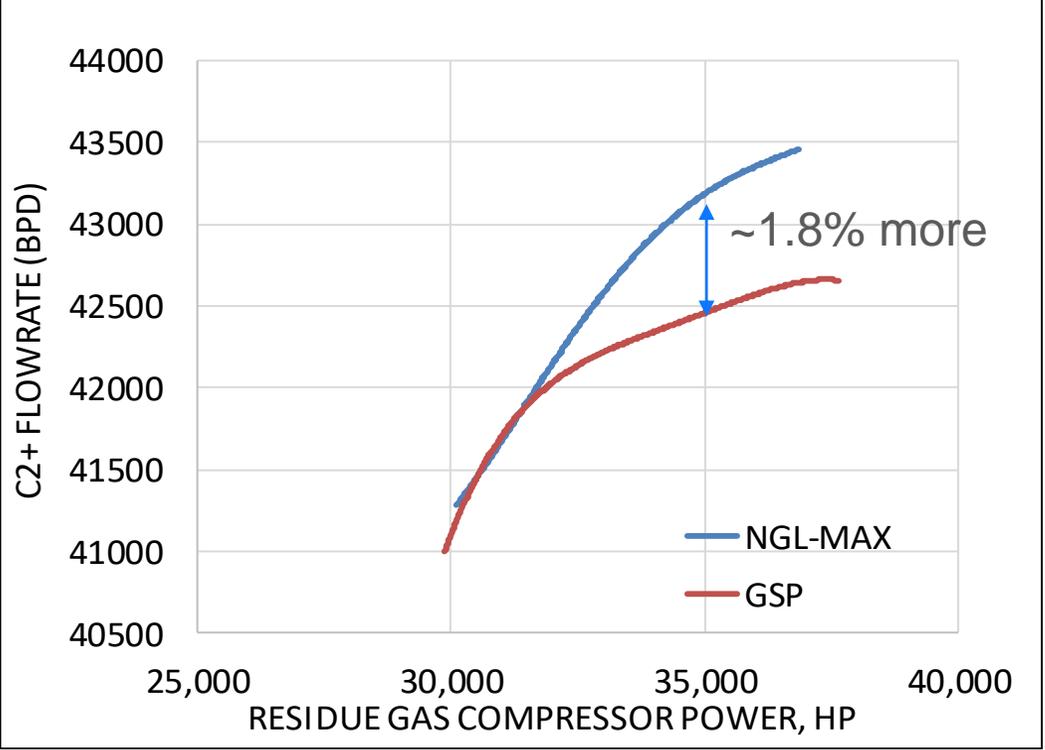
	Residue Gas	C ₂ + Product (Ethane Recovery)	C ₃ + Product (Propane Recovery)
Pressure, barg	65	55	55
Temperature, °C	50	Resultant	≤50
HHV, Btu/scf	Min 950	-	-
HC Dew Point, °C	-5	-	-
Methane Content	-	Max 0.5% Vol	-
Ethane Content	-	-	Max 2 mole% C ₂ /C ₃

GSP vs. NGL-MAX Ethane Recovery Performance

Recovery vs. Spec Power



Liquid Products Recovered

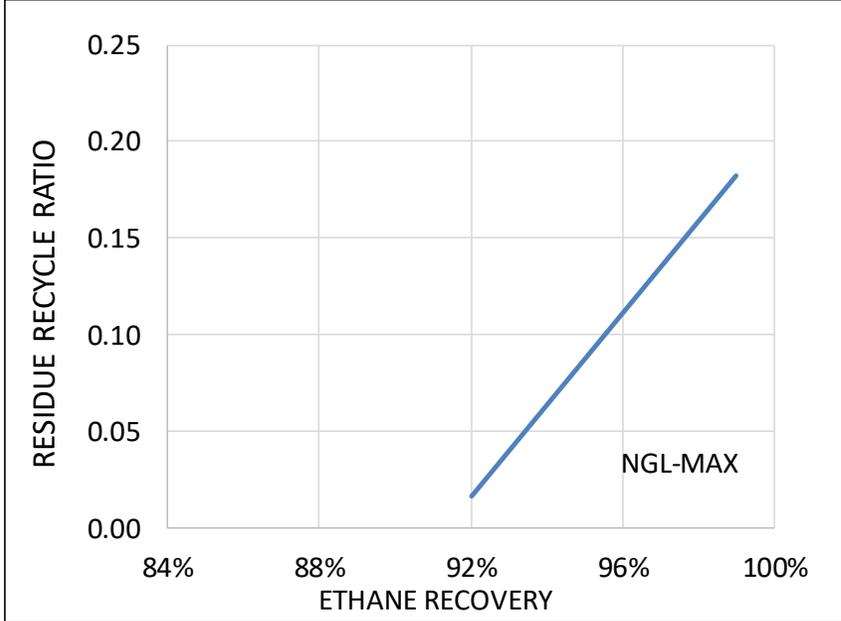
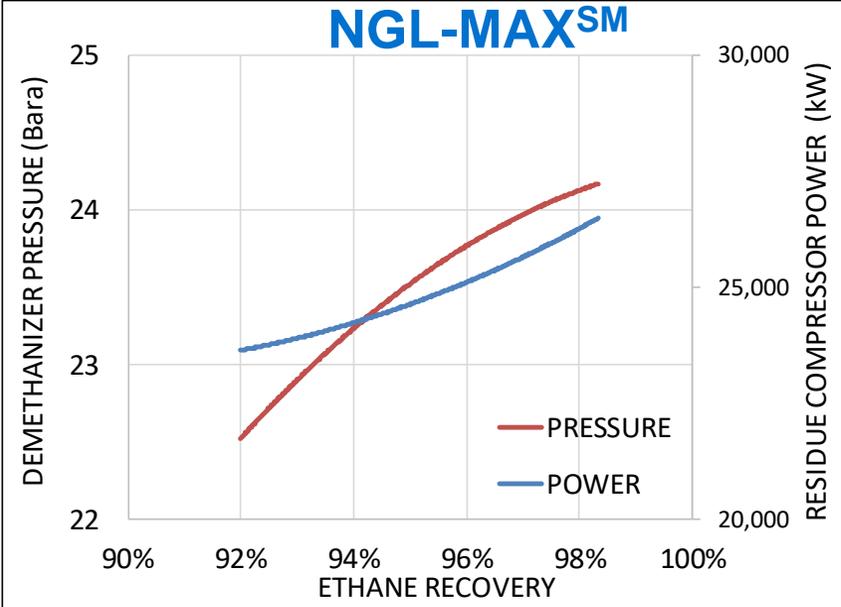
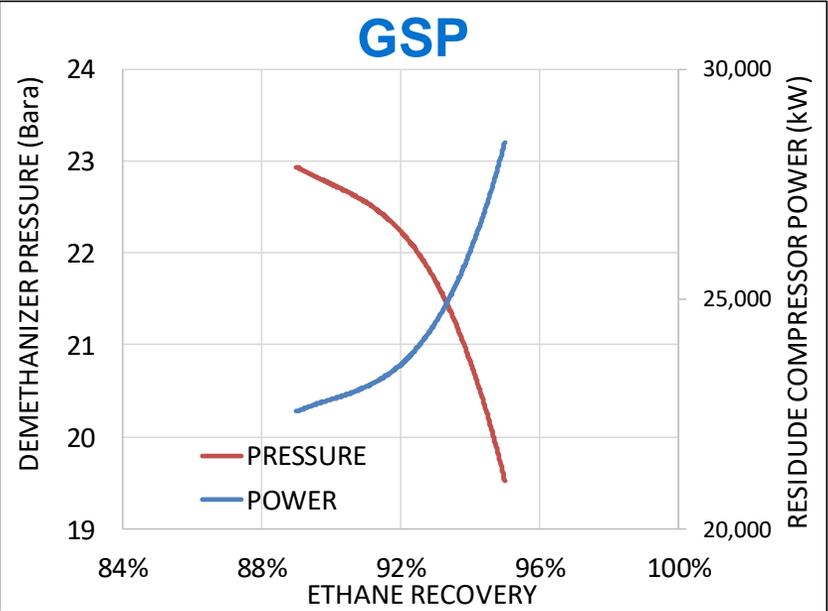


For <92% Ethane Recovery, GSP vs. NGL-MAX comparable

For >92% Recovery, an advanced process like NGL-MAX with higher product recovery improves economics: Identical balance of the plant cost except NGL Recovery and Compression



Demethanizer Pressure – Key Design & Operating Parameter



Benefits of Higher Demethanizer Pressure

Efficiency

- Lower residue compressor power

Equipment Cost

- Smaller demethanizer diameter
- Lower Residue compressor inlet actual volumetric flow

Operating Flexibility

- Higher CO₂ tolerance



Parameter	High CO ₂ Feed Gas
Pressure, barg	65
Temperature, °C	50
Flow, MMSCF/D	600
Component	Mol %
N ₂	0.3
CO ₂	1.5
Methane	87.1
Ethane	5.5
Propane	3.0
i-Butane	0.6
n-Butane	1.1
i-Pentane	0.4
n-Pentane	0.3
Hexane+	0.2

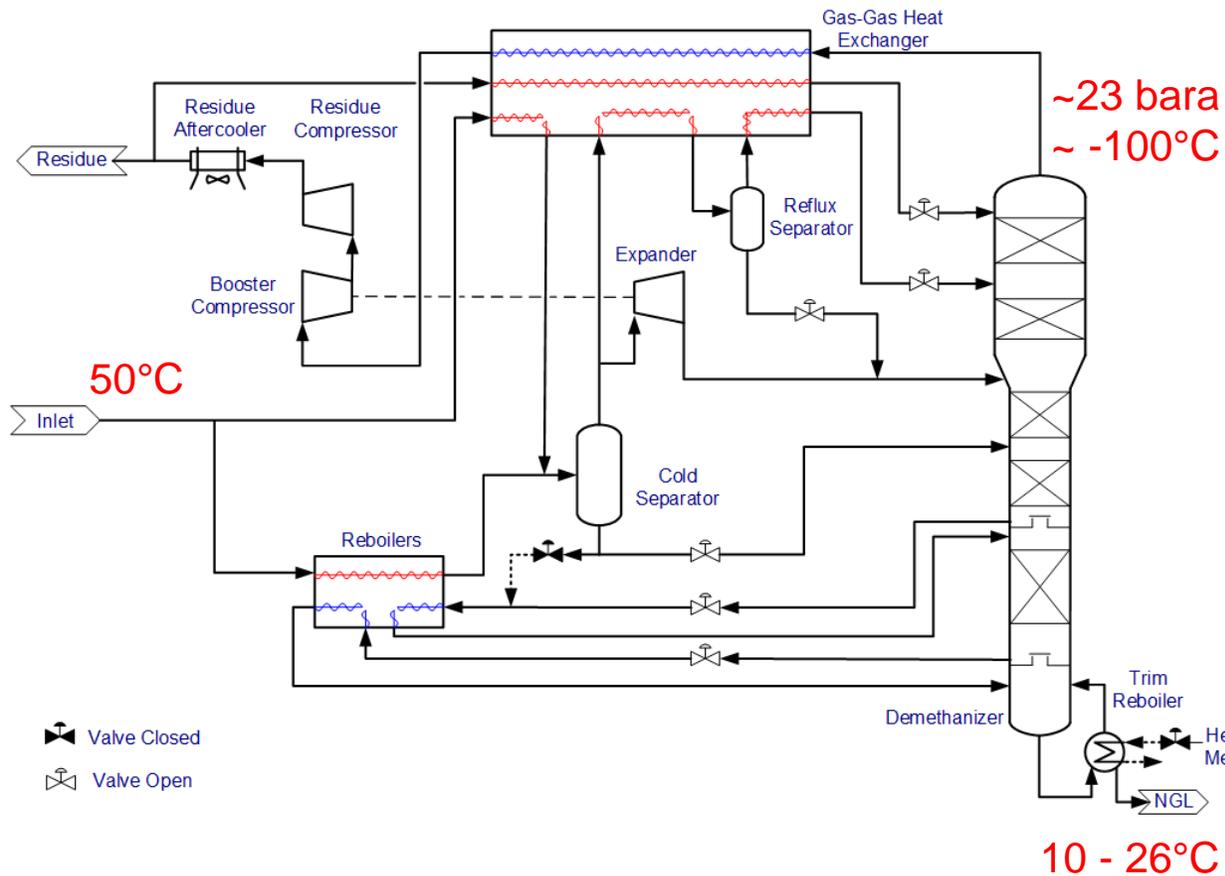
	GSP	NGL-MAX
Ethane Recovery	90.1%	96.1%
Propane Recovery	98.53	99.97%
Total Liquids, BPD	43,037	44,648
Residue CO ₂ Content, mol%	0.50%	0.37%
NGL CO ₂ Content, mol%	9.08%	9.66%
Demethanizer Top Pressure, bara	20.2	21.3
Demethanizer Top Temperature, °C	-99.0	-104.2
Residue Gas Flow, MMSCFD	530.0	527.0
Residue Compressor Power, kW	26,752	28,336

Compared to GSP, NGL-MAX Process can achieve:

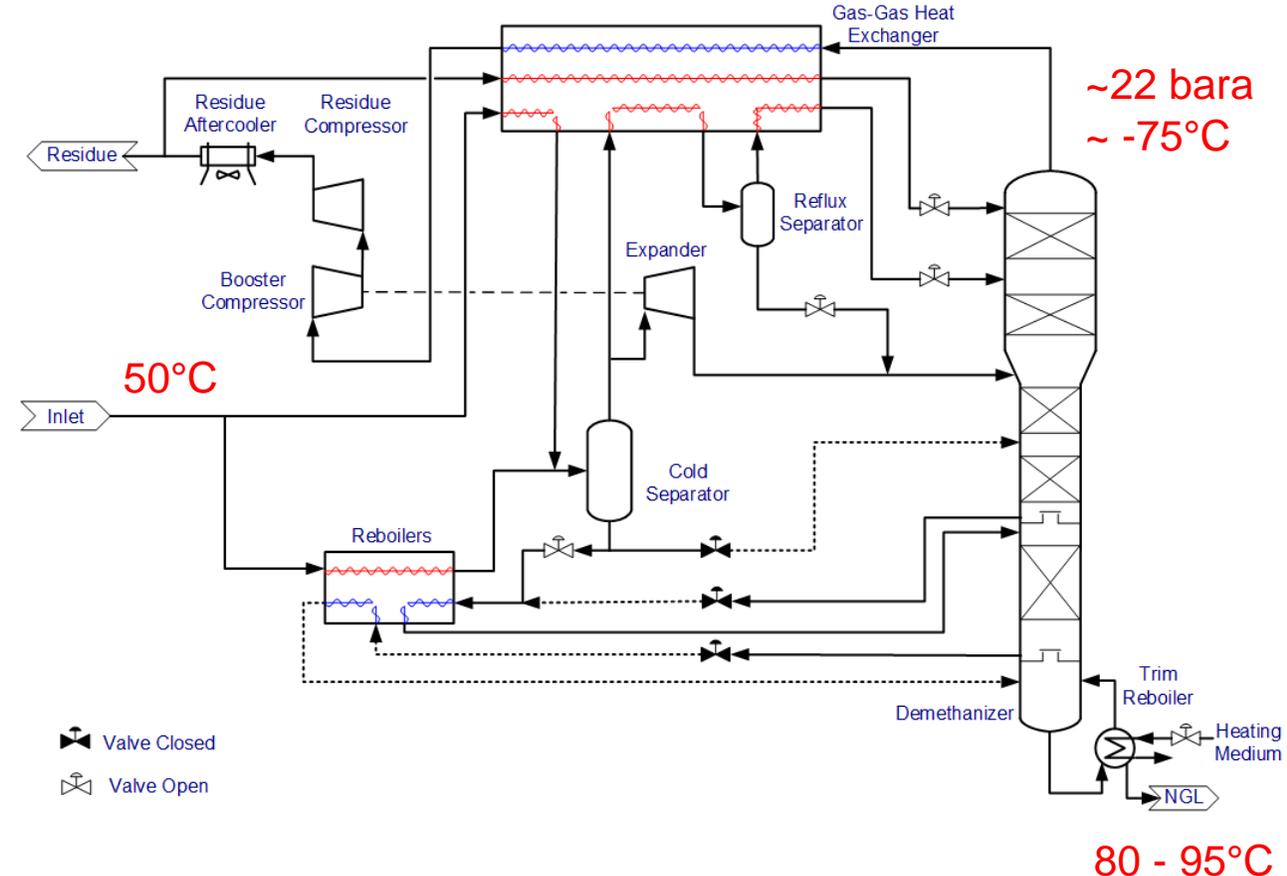
- ~6% higher Ethane Recovery can be achieved
- ~ 3.8% more liquids

Ethane Recovery and Ethane Rejection Capability

Ethane Recovery Mode



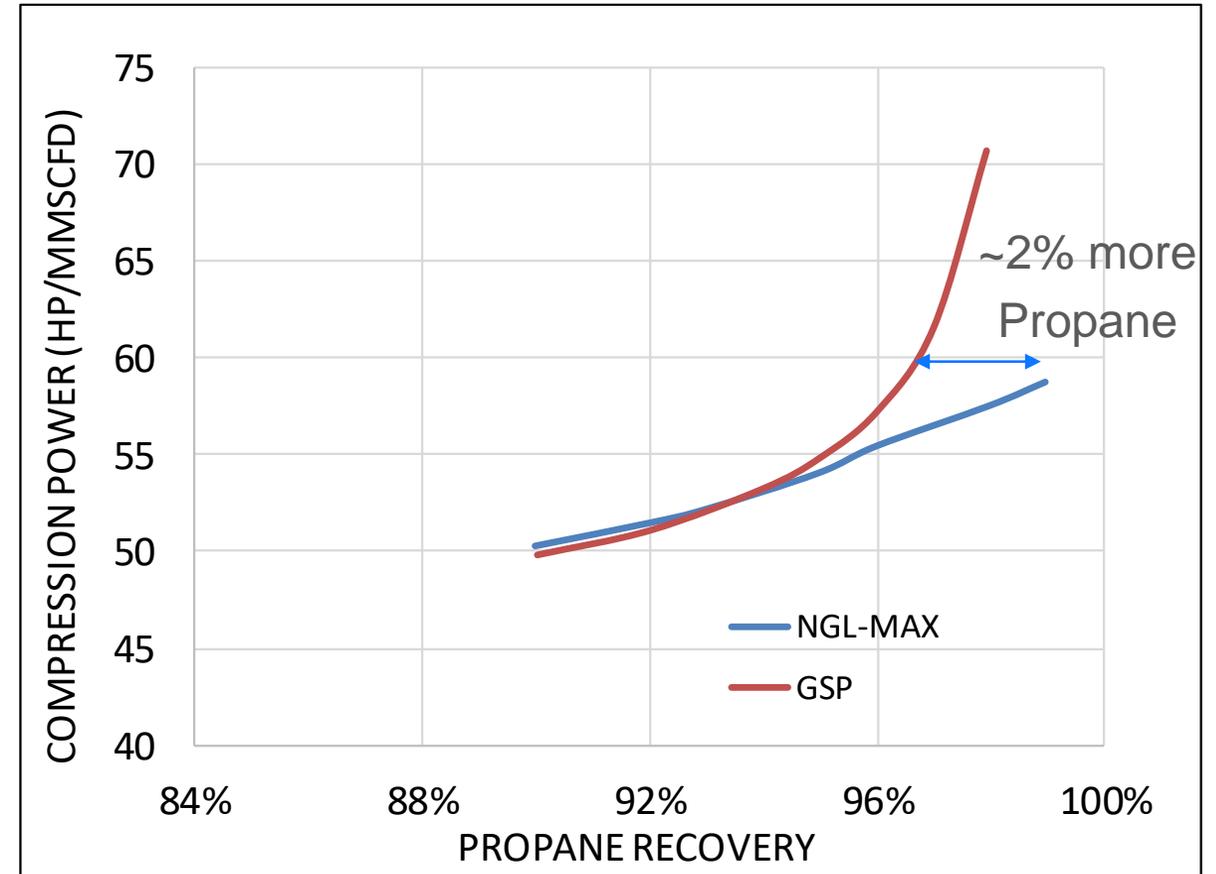
Ethane Rejection Mode



- Switching between Ethane Recovery to Rejection can be achieved by supplemental heat with a Trim Reboiler.
- Heat Integration needs to be modified.

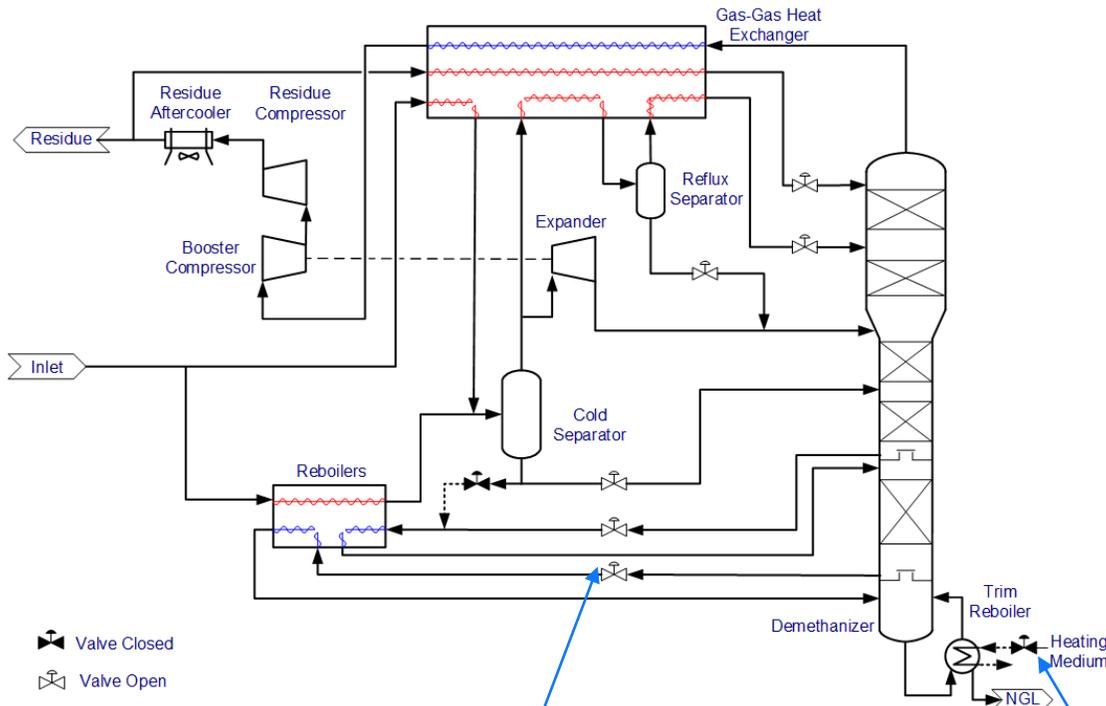
Ethane Rejection Performance

	GSP	NGL-MAX
Ethane Recovery	1.1%	1.1%
Propane Recovery	96%	98%
Total Liquids, BPD	23,775	24,036
Demethanizer Top Pressure, bara	21.1	23.5
Demethanizer Top Temperature, °C	-80.5	-81.5
Residue Recycle Flow, MMSCFD	-	41.2
Residue Gas Flow, MMSCFD	566.8	566.4
Trim Reboiler Duty, kW	9,114	9,964
Residue Compressor Power, kW	25,623	25,741



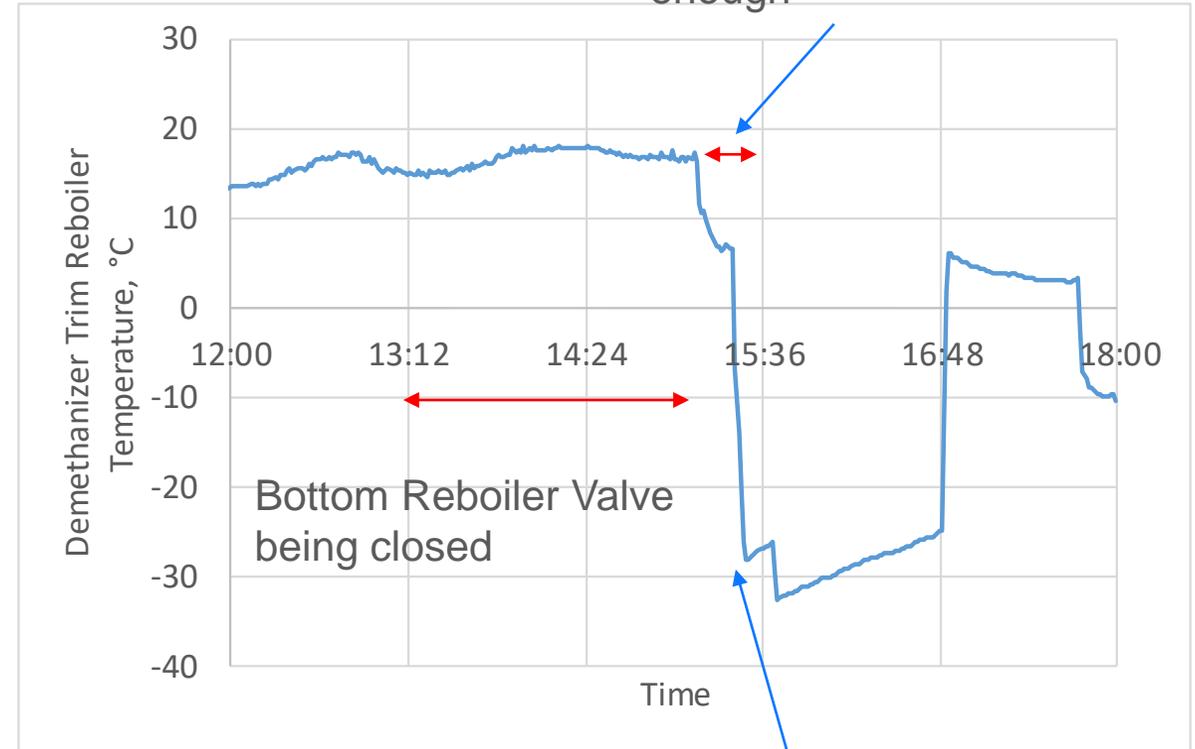
Lessons Learned - Online Transition Gone Wrong

Plant Initially Running in Ethane Recovery Mode Switching to Ethane Rejection



Chain Operated Bottom Reboiler Isolation Valve

Trim Reboiler Hot Oil Supply Valve



Trim Reboiler not able to ramp fast enough

Bottom Reboiler Valve being closed

Low temperature shutdown

Online Recovery-Rejection Transition Recommendations

Ethane Recovery To Rejection

- Trim Reboiler while not required during normal Ethane recovery mode, Hot Oil Supply Valve should not be tied to a permissive or operating mode switch in control system.
- Cold “Hot-Oil” does not flow well, steady demethanizer bottom temperature is not sufficient, ensure Demethanizer bottom temperature increasing before closing the Bottom Reboiler isolation valve.
- Slowly close Bottom Reboiler isolation valve, automated control valve instead of chain operated manual valve if mode switching will be done frequently.

Ethane Rejection To Recovery

- Ensure NGL pumps are ready to extra flow, in ethane recovery ~2x Liquid Product.
- If liquid treater/amine is used, ensure it can keep up with the increasing Liquid Product flow.
- If not, the plant can trip due to high liquid level in the demethanizer/surge drum or off-spec product can go to NGL pipeline / users.

General

- Allow for 8-10hrs for switching between modes
- Watch Brazed Aluminum Heat Exchanger inlet/outlet temperatures and stay within the manufacturer limits.



NGL-MAX can achieve product recovery flexibility and adjust rapidly to changing market conditions and adapt ethane price volatility or ethane demand.

- Ultra-High Ethane Recovery, 99+%
- Deep Ethane Rejection, <2% Ethane while >98% Propane Recovery
- Minimal cost to provide dual mode flexibility, typically only larger Trim Reboiler.

Open-Art can be practiced by an experienced engineer as well an inexperienced engineer

Licensed Technologies often practiced by or under supervision of Subject Matter Experts

- Comes with Performance Guarantees
- Higher Product Recovery and Operating Flexibility
- Overall improved project finances and reduces risk

